



*A Case of Ligature of the Abdominal
Aorta Just Below the Diaphragm,
the Patient Surviving for Forty-
Eight Days:*

*With a Proposed Instrument for the Treatment of Aneurisms
of the Abdominal Aorta by Temporary Compression.*

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VINCENT T., aged fifty-two years, married, and a laborer, was admitted to the Jefferson Medical College Hospital under the care of Prof. James C. Wilson, November 8, 1899.

Family History. His father and mother died at about seventy years from unknown causes; one brother is living and well, and one sister died of pneumonia at fifty-seven years; there is no tubercular history.

Personal History. He had measles during childhood; has never had scarlet fever, diphtheria, nor typhoid. He had an attack of left-sided pleurisy twenty years ago, which was followed by a good recovery. There is probably a syphilitic infection.

His present trouble began about two months before admission, when he had an attack of severe pain in the epigastric region, radiating to the back. The pains varied a good deal in their intensity. On admission he had constant pain in the epigastrium, his bowels were constipated, and his appetite poor. The urine was clear, straw-colored; specific gravity 1020; reaction acid; neither albumin nor sugar was present; urea 1.5 per cent. By the microscope there were crystals of oxalate of lime, amorphous urates, a few epithelial cells, no pus, blood, or casts. His radial arteries were not noticeably atheromatous.

Prof. Wilson asked me to see the patient with himself, to consider the question of operative interference.

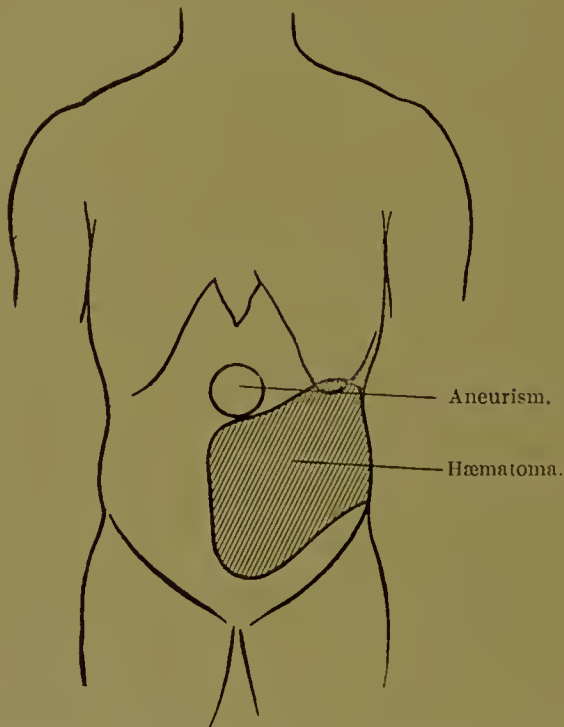
Physical Examination. His general condition is poor. There is a small bed-sore over the sacrum and coccyx. The viscera of the chest are normal, and also the viscera of the abdomen, with the following exception: Half-way between the ensiform cartilage and the umbilicus (Fig. 1) is a tumor nearly 7 cm. in diameter. It is globular, perceptible to the eye, as it slightly raises the anterior abdominal wall. On palpation a distinct expansile pulsation is perceived, and there is a distinct bruit on auscultation. Unfortunately, I did not observe whether the bruit was propagated in the line of the aorta downward. The diag-

¹ Read at the Thirteenth International Medical Congress in Paris, August, 1900.

nosis of aneurism was made, and Prof. Wilson and I thought it to be a case suitable for wiring and electricity if, on exploratory operation, it was found practicable to reach it. On proposing this to the patient he rejected operation and left the hospital.

November 22d, five days later, he was brought back to the hospital in the ambulance, complaining of great pain in the left side of the abdomen. Examination showed that the entire left side of the abdomen from the lower border of the ribs to the left iliac region, and extending about 3 cm. to the right of the middle line, was occupied by a large, soft, smooth, elastic tumor. (Fig. 1.) His condition was very alarming; he was almost in collapse. His pulse was very weak, and it seemed as though he could scarcely survive. Under small doses of alcoholic

FIG. 1.



Site of the aneurism and the hæmatoma resulting from its rupture.

stimulants, rest, and frequent liquid food he gradually recovered, so that he was in a condition for an exploratory operation. Evidently the aneurism had ruptured, and I feared a fatal hemorrhage if nothing was done.

Exploratory Operation, November 29th. An incision was made at the outer border of the left rectus. As soon as the abdominal cavity was opened a mass of almost the same color and consistence of the spleen appeared in the wound. A few minutes' exploration showed the descending colon to the right of this mass. It was then clear that a large retroperitoneal hemorrhage had taken place from the aneurism, and that the large, dark mass was an immense hæmatoma under the external layer of the mesocolon. This was confirmed by thrusting a

grooved director into the mass. I introduced my hand toward the epigastrium, and could seize in the palm of the hand the aneurism, which had not changed its shape or size to any notable extent. That it was connected with the aorta was evident.

In view of the condition of the man, the size of the clot, and the certainty of enormous hemorrhage if I removed the clot, I closed the abdominal wound. During his first stay in the hospital, and for the two days prior to the operation, his temperature had ranged from about 97° to 99° F. The day after the operation the temperature rose to 101.2° F. and then fluctuated from about 99° to 100° F., falling to the normal by December 2, the third day after the operation. The abdominal wound healed without incident, and the man's general condition improved from day to day. Prof. Wilson and I then determined to try the effect of hypodermatic injections of a 2 per cent. solution of gelatin in sterile normal salt solution. Injections were made December 4th, 5th, 11th, and 16th, of 48 c c. each.

No effect followed these injections, and as his condition was certainly growing no better, and he agreed now to a second operation, this was determined upon. Our intention was to wire the sac and use electricity; but the facts found at operation led me to ligate the aorta.

Second Operation. Ligation of the Abdominal Aorta, December 12, 1899. An incision was made in the median line, 8 cm. long, and was finally prolonged up to and alongside of the ensiform cartilage and down to the umbilicus. As soon as I had torn through the omentum in order to reach the aneurism the pancreas presented itself, lying only 2 to 3 cm. posterior to the abdominal wall. The entire pancreas had evidently been lifted up and thrust forward by the aneurism. Passing my hand in above the pancreas, between it and the stomach, I readily found the aorta. On each side of it the pillars of the diaphragm were at once felt. The working space above the aneurism was 5 to 6 cm. There were no evidences of atheroma or of other disease in the aortic wall. In view of the apparent possibility of the ligation of the aorta, I decided to attempt it, as a fatal result was inevitable, if nothing was done. First, with the left forefinger, I tore through the tissues on each side of the aorta, and in doing so distinctly felt some of the fibres of the pillars of the diaphragm give way. I readily separated the vena cava from the aorta, and so had the aorta isolated on both sides. With a long-handled aneurismal or pedicle needle with a large curve to my left I then passed four strands of disinfected floss silk from the left side of the aorta to the right. I passed the needle toward the vena cava rather than from it, because my left forefinger protected the vena cava from injury, and I felt that this was much less dangerous than passing the needle in the opposite direction. Then came the greatest difficulty, namely, the finding the eye of the needle and disengaging the thread. The working space between the aneurism, which was fixed below, and the border of the ribs, stomach, liver, and diaphragm above, was so contracted that though I could feel the point of the aneurism needle I could scarcely get access to it in order to seize the threads with forceps or other instruments or even to see the threads. Accordingly I made a transverse incision, about 4 cm. long, to the left. This incision did not divide any artery which could be recognized as either a continuation of the internal mammary or superior epigastric.

It added, however, less to the case of the manipulation than I had hoped. I should certainly not recommend it in another case lest it should interfere with the re-establishment of the circulation. Finally, with great difficulty, by energetic retraction of the tissues, I was able to see the thread and disengage it from the needle. I then tied the aorta, one assistant having his hand on the aneurism and another on the left femoral. When tied, pulsation ceased in the femoral, but we were much less certain of its cessation in the aneurismal sac. It was very difficult to distinguish between true pulsation in the sac and the push of the blood-current in the aorta above the ligature, which was transmitted to the sac with each beat of the heart. Finally, however, we were convinced that pulsation had ceased in the sac. As soon as the ligature was tied the man's head, face, and neck became deeply congested and almost livid. This lividity gradually subsided in a few hours. In a few minutes after the ligature was tied the aneurismal sac had shrunk to less than one-half its original size.

The following observations were made by Dr. Harbaugh, who gave the ether: "Duration of anæsthesia, one hour and twenty-five minutes; 5 ounces of ether were used. He received once $\frac{1}{100}$ grain of atropine sulphate and, four times, $\frac{1}{20}$ grain of strychnine sulphate; he also received one enema of 2 ounces of black coffee and 1 ounce of whiskey. 2 P.M., anæsthetic begun. 2.10 P.M., pulse 100, weak, and easily compressed; $\frac{1}{20}$ grain strychnine sulphate hypodermatically. 2.30 P.M., $\frac{1}{20}$ grain strychnine sulphate hypodermatically. 2.40 P.M., $\frac{1}{100}$ grain atropine sulphate hypodermatically. 2.50 P.M., pulse 70. 3 P.M., pulse 90; $\frac{1}{20}$ grain strychnine sulphate. 3.10 P.M., ligature applied; pulse rose from 90 to 130. 3.15 P.M., $\frac{1}{20}$ grain strychnine sulphate; enema, coffee, 2 ounces; whiskey, 1 ounce."

During the entire operation the pulse was very irregular, weak, and easily compressed; respiration was regular and normal. Neither the splenic nor the portal vein was seen. No artery was seen. When the hand was first introduced I thought I could feel a large vessel beating above the point where the ligature was afterward applied, but this was probably an error. The abdomen was then flushed out with salt solution and closed. The legs, which were cold, were wrapped in cotton and surrounded with hot-water bags. Sensation was but little disturbed, and motion was not impaired.

December 20th, 8.40 P.M. Femoral artery was found to be pulsating very slightly. *22d*. Aneurismal bruit again slightly perceptible. The legs had regained their natural warmth. *24th*. An attack of moderately acute cystitis. *25th*. Superficial stitches removed. *27th*. Pulsation of the internal mammary and deep epigastric probably felt. *28th*. The area of the clot on the left side of the abdomen was distinctly smaller.

By January 10, 1900, he was so much improved that he sat up out of bed for two or three days, to relieve the monotony of his prolonged stay in bed and to take pressure off his bed-sores; but I thought it dangerous to allow him to continue any exercise.

By January 28, 1900, the clot on the left side of the abdomen, instead of overlapping the median line by 3 cm., failed to reach the middle line by 3 cm. The aneurismal bruit and distention were not so marked as before. The bruit could not be heard below the aneurism in the neighborhood of the umbilicus. The bed-sore, which existed when he entered

the ward, had been dressed with pure bovine, and was distinctly improved.

On January 9th, 48 c.c. of gelatin solution were again injected hypodermatically. As 48 c.c. gave him some pain, 24 c.c., which were not painful, were injected on the following dates: January 15th, 16th, 17th, 18th, 19th, 20th, 21st, 23d, 24th, 25th, and February 3d, but as no good result followed they were abandoned. On January 14th the tumor in the abdomen was carefully measured and found to extend from the tenth rib to the level of the anterior superior spine, and failed to reach the middle line by 6 cm.

On January 28th he had a marked chill, his temperature rising to 103° F. at 2 A.M.. At 9 A.M. it had fallen to 99° F. On the 29th at 8.45 P.M. another similar chill and an identical rise of temperature took place, and by the next morning at six the temperature had fallen to 98.6° F. On the 30th the plasmodium of malaria was discovered in his blood. The administration of quinine up to 25 grains a day, and then later in diminishing doses, prevented any repetition of the chill.

February 5th the patient complained all the afternoon and evening of pain in the region of the aneurism, radiating to the left groin and knee. His temperature also had risen a little above 100° F. On the 6th he was still doing badly. It was noted by Dr. Snell, the house surgeon, that the aneurism was apparently smaller. At 2 P.M. he rapidly grew weaker, the aneurism pulsated more freely, his pulse was very weak, his lips were blanched, and his expression anxious. Strychnine (gr. $\frac{1}{30}$) was given, and a saline enema with whiskey and external heat applied. At 3.20 P.M. he died.

The amount of urine passed before the operation varied from 19 to 40 ounces; but, as a rule, was small. After the operation he passed, on December 21st and the succeeding days until January 1 (eleven days), the following amounts: 12, 4½, 14, 21, 31, 21, 35, 40, 45, 39, 31 ounces, and after that his usual amount. Unfortunately, I did not examine it for albumin or other pathological changes. The kidneys were found to be normal at the necropsy.

Necropsy. On account of the circumstances of the case it had to be done hurriedly, as his family were clamorous for the body. It was limited to the abdomen and head. Unfortunately, the spinal cord could not be obtained. The necropsy was begun a half-hour after he died by Prof. H. F. Harris, Associate Professor of Pathology, and his report is as follows:

"Body of an emaciated male; skin pale and of a slightly yellowish hue. Mucous membranes likewise pale. Post-mortem rigidity has not begun. Temperature of the body almost that of the living person.

"In the abdominal wall there are three scars, one extending from the tip of the ensiform cartilage to a point just above the umbilicus; it is 1 mm. wide and 12.5 cm. long, and consists entirely of cicatricial tissue. Four centimetres to the left of the umbilicus there is a second scar, which extends from a point just above the umbilicus to the crest of the ilium; it is 17.5 cm. long and entirely healed. Running to the left from a point in the centre of the first scar referred to is a scar 4 cm. in length. It is also thoroughly healed.

"On cutting into the abdominal wall only a very small amount of adipose tissue is found. The muscles are rather pale, otherwise the wall

presents no abnormalities. On opening the abdominal cavity great quantities of dark fluid blood and many clots are found. The omentum is adherent to the abdominal wall at the seat of the first scar. Beneath the scar last described several loops of small intestine are adherent to the abdominal wall; there is also a large tumor, which becomes apparent on opening the abdominal wall in this situation.

"The left pleural cavity is found normal on opening the chest. Scattered here and there are a few adhesions (evidently quite old) between the layers of pleura on the right side.

"Lungs are normal.

"On opening the pericardial cavity the lining membrane is found to be normal. Cavity contains 15 c.c. of fluid.

"Left side of the heart firmly contracted; right side empty and exceedingly flabby. Heart is rather small; it is in every way normal.

"Spleen is bound to all neighboring structures by old adhesions. Capsule is thickened, especially on its convex portion. The organ is slightly enlarged and its substance is tougher than normal. Weight, 175 grammes.

"Left adrenal is normal. Left kidney is normal in size and consistency, though perhaps slightly paler than usual. The capsule strips readily. Cortical and medullary portions normal. Weight, 140 grammes.

"The left ureter is pushed greatly forward and inward on account of a large tumor-like mass which occupies the left lumbar region.

"The tissues around the right kidney are intensely ecchymotic, and are much softer.

"Right adrenal is normal. Right kidney resembles in every way its fellow. Weight, 130 grammes.

"Right ureter is normal.

"On opening the bladder the mucosa of its posterior surface is covered by numerous rounded elevations, the largest of which are 1 cm. high and 1 cm. in diameter, the smallest being pinhead-like projections. These elevations are covered by a whitish deposit, which apparently consists of triple phosphates. On section, toward their free ends, these tumors are found to be of a dark, slaty color, but as the base of the tumor is reached this color gradually gives way to a grayish appearance. The tumor substance is well defined from the normal tissue beneath. The tumors toward their bases are encircled by a slight constriction, giving them the appearance of being somewhat pedunculated. The surrounding mucosa is bright red.

"The liver is small, weighing 1150 grammes. Its substance is soft and friable and rather pale in color.

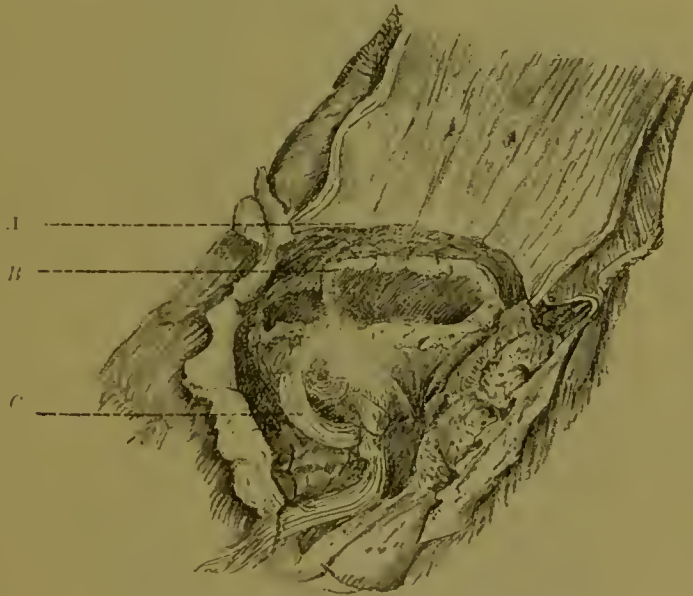
"Pancreas is normal and weighs 118 grammes.

"Gastro-intestinal tract is normal.

"On removing the abdominal aorta this vessel is found to be entirely cut through at the point where it had been ligated, which is just below the diaphragm. (Fig. 2.) From this opening in the vessel blood had infiltrated downward into the tissues beneath the peritoneum, and had finally burst into the peritoneal cavity just over the right kidney. There had evidently been also some oozing of blood from the wound at the place where the vessel was tied. On dissecting further downward, 3 cm. below the point where the vessel is divided, an irregular, rounded cavity was found on the posterior aspect of the aorta; its greatest diam-

eter, which is longitudinal with the vessel, is exactly 2 cm. and the shortest is 3 mm. less. (Fig. 3.) The edges of this opening in the aorta are perfectly smooth, and are continuous on the inside with the intima of the bloodvessel and on the outside with the sac of the false aneurism about to be described. Just posterior to this opening, and extending 1 cm. upward from its upper margin and 5 cm. downward from its lower edge, is a rounded cavity that is flattened antero-posteriorly. This cavity is evidently the result of the opening in the aorta forming a false aneurism in this situation. The anterior wall of this sac is made up partially by the external coat of the aorta, which becomes continuous with the compact wall of tissue on either side, which forms the remaining part of the anterior boundary of the aneurism. This sac curves backward to the side of the vertebral column and be-

FIG. 2.



Site of ligation of aorta, viewed from in front.

A. Edge of upper portion of the aorta. B. Edge of lower portion of the aorta. Between A and B is the place of ligation, followed by ulceration of the ligature completely through the aorta. C. The ligature as found at the necropsy.

comes continuous with the periosteum of the bones composing it. The bodies of the eleventh and twelfth dorsal and first lumbar vertebrae form the remaining part of the posterior part of the sac. The bodies of these vertebrae are deeply eroded, although the intervertebral cartilages are not affected. In all of its diameters, except antero-posteriorly, the exact measurement of which could not be determined, the diameters of this sac are 6 cm.; but as the antero-posterior diameter is but little less than the others it is, therefore, evident that the sac was almost round. The tissue forming the inner wall of the cavity is at all points quite dense—resembling fibrous tissue—and can scarcely be differentiated from the intima of the bloodvessel, with which it communicates. This sac has ruptured on its lower left side; the blood, penetrating into the muscle and tissues back of the peritoneum and infiltrating down to the

brim of the pelvis on the left side, has produced a tumor-like mass 24 cm. long and 6 cm. in diameter at its widest portion.

"It will be observed from the above description that there is no aneurism of the aorta itself, there being merely an opening in the posterior wall. The intima of the bloodvessel both in the region of the opening and above and below is in a remarkably good condition, considering

FIG. 3.



Aorta and aneurism seen from behind.

A. The opening in the aorta. B, B. Wall of sac of false aneurism. C. Opening where wall of sac ruptured. D. Large clot occupying left side of abdomen. E. Bifurcation of aorta.

the very extraordinary condition of the lesion just spoken of. There are here and there a few minute areas of what appears to be atheroma, and the intima is perhaps somewhat thickened, and shows a somewhat more irregular surface than normal. There are no clots found in the bloodvessel either above or below the point of ligation, nor were there any changes which indicate the formation of recent thrombi. This is

of much importance, in view of the fact that the vessel was eroded through the point of ligation.

"The dura of the brain appears to be entirely normal. The pacchionian bodies are present to an unusual degree on the surface of the brain. In some of the sulci the pia arachnoid appears to be slightly thicker than usual; this change is not a very marked one. The ventricles of the brain are normal. Substance of the brain is normal. None of the vessels, either of the meninges or the brain substance, appear to be in the slightest degree altered.

"*Microscopical Report.* Specimens from the kidney, liver, spleen, brain, sections of the tumors of the bladder, pieces of the wall of the false aneurism, and specimens from the abdominal aorta at the point where it opened into the false aneurism, from the point at which the vessel was tied, and pieces of the wall both above and below these areas were fixed in Heidenhain's solution, cleared in cedar oil, embedded in paraffin, sectioned, and the sections stained with toluidin blue alone, and with eosin, hæmatoxylin alone and with eosin, hæmatoxylin and picric acid, and by the methods of Weigert for fibrin, Unna for collagenous and elastic tissues, and by the method of Van Gieson.

"On examination the sections of the kidney are found to be practically normal, there being only in a few situations a very slight degree of interstitial change. Further than this no alterations existed.

"On examination but little change is found in the liver. There is, however, a slight degree of atrophy of the liver cells around many of the central veins of the lobules, and taking the place of these cells there are quite a number of lymphoid and plasma cells. There is in and between the liver cells in the vicinity of the alterations just referred to quite an amount of golden-yellow pigment. Around some of the fibrous septa which pass into the liver substance there are found here and there small collections of cells, these resembling in every way those occurring around the central veins of the lobules. The liver cells appear to be normal in other situations.

"Microscopical examination of the spleen shows a very marked thickening of the trabeculae which traverse the substance of the organ. Around the edges of these trabeculae, and in many instances lying entirely free in the splenic substance, there are found numerous perfectly typical plasma cells, while in addition there are many cells which, though resembling plasma cells in many particulars, do not exhibit the same affinity for basic dyes that is shown by the true plasma cell; these peculiar cells correspond to what are called by some writers atypic plasma cells. No other alterations of any moment are found.

"Microscopical examination of sections of the brain show the substance and the membrane to be entirely normal.

"Bladder: Sections of the tumors of the bladder prove to be of very unusual interest, inasmuch as they reveal the fact that the neoplasms are myxomata—tumors which are exceedingly rare in the bladder. Around their edges these tumors are covered by almost normal bladder epithelium, but on passing upward toward their apices this coat at some points always becomes detached from the basement membrane and hangs loosely in the interior of the bladder; beyond this point no epithelium is, as a rule, present; but occasionally in one of the depressions, which are quite numerous on the surface of these tumors, a few epithelial cells may be found. In the majority of the tumors no very marked change

is observed in the tissues which are exposed to the contents of the bladder, there being only a mild degree of cellular infiltration along the edges, and always considerable enlargement of the bloodvessels which are here present. In other instances the superficial structures that are uncovered by the epithelium have undergone necrotic change, and may be seen lying above and still attached to the living tissues beneath. In both instances, though especially in the latter, the mass of cells which is collected along the borders of the inflamed tissue presents the characteristic peculiarities of the polymorphonuclear leucocyte, but mixed with them are always a number of lymphoid and plasma cells. Along the edges of the tumor multitudes of bacteria are found. A little deeper down there are much larger collections of lymphoid and plasma cells, the latter being especially large and numerous; they occur in greatest number around the bloodvessels. At this point large, stellate, basophilic bodies are observed, and, becoming more numerous the deeper the tumor is penetrated into, they finally make up quite a large part of the tissues which lie toward the bases of these new-growths. These bodies contain several feebly staining nuclei, with distinct nucleoli, and though exceedingly irregular in form, vary in diameter from about 5 to 15 or 20 μ . Their protoplasm gives the iron reaction. They are evidently cells that have become swollen, and within their protoplasm there has been elaborated some substance which is intensely basophilic. Between these bodies there is a delicate stroma consisting of collagenous and elastic tissues. Between the bundles of this tissue are numerous spaces which contain connective-tissue cells, a quantity of a finely granular acidophilic substance, and also quite an amount of fluid. This tissue extends downward into the wall of the bladder only a short distance, but more or less separates the bundles of muscle-fibres in the most superficial portion of the muscular wall of the viscus. As before mentioned, these tumors undoubtedly belong to the class of myxomatous new-growths, but contain a certain amount of fibrous and elastic tissue.

"The inner wall of the aneurism is made up of more or less altered collagenous tissue, in the interstices of which there are breaking-down red blood-cells, a few polymorphonuclear leucocytes, lymphoid, plasma, connective-tissue cells, and quite a number of typical giant-cells, the protoplasm of which is intensely basophilic. The cells in these situations show their usual staining peculiarities, but the connective tissues have become decidedly basophilic. In some situations, in the interspaces between the fibrils of the connective tissue, there is a peculiar, entirely homogeneous substance which appears greenish in the specimens stained with toluidin blue and eosin; this substance frequently entirely surrounds the cells, but does not interfere with their staining reactions. Somewhat deeper the connective tissues begin to react in a normal manner to aniline stains, the number of cells, except the connective tissue ones, becomes gradually less and less, the peculiar homogeneous substance referred to is no longer found, and at a somewhat greater distance the tissues are found to present an entirely normal appearance. It may be mentioned as a rather interesting fact that the connective-tissue cells that lie in this connective tissue are much elongated, and that their long axes are invariably parallel with the lining of the aneurism; this is undoubtedly an effect of pressure.

"On tracing the lining of this aneurism to the opening in the aorta it is found that there is no well-marked point of union between the tissues

composing this and those which make up the wall of this bloodvessel—the tissues gradually merging into each other. As the point is reached where the opening exists it is found that while the superficial tissues of what is now a part of the wall of the aorta show a basophilic reaction, the muscle-fibres which lie at a lower level present that peculiar modified basic reaction which is seen in the granules of mast cells (mucin reaction). As the turn is made into the aorta itself both of these appearances just described gradually give way to those which characterize the normal appearance of this vessel.

“A careful examination of sections of the aorta both above and below this opening shows that an exceedingly small amount of change is present in the vessel. Here and there, however, are found slight thickenings in the intima, due to an increase of fibrous tissue, and, in addition to the cells which are normally present in the part, there are, as might be expected, quite a number of lymphoid and plasma cells. In the muscular coats there are also small areas in which the muscle-fibres present the mucin reaction; further than this no change is found in the vessel.

“Specimens from the aorta taken from the point where it was cut through by the ligature show surprisingly little change. In this situation the edges of the vessel present a ragged, irregular surface, and in the depressions between the more elevated portions small collections of blood are seen. At a distance of about 0.5 mm. from the end of the vessel where cut through, and in its muscular wall, there is quite a collection of lymphoid and plasma cells and polymorphonuclear leucocytes, and the tissues in this area have been to quite a marked degree replaced by them. At one side of this collection of cells there are found a few cocci which stain by Gram's method; in addition there are some forms which have the appearance of short bacilli; but these may be nothing more than several cocci lying close together, which seems not improbable.

“These bacteria are entirely surrounded by the wall of the bloodvessel, and evidently were not present at any other point; this accounts for the fact that cultures made from the vessel and from its contents remained sterile. These bacteria certainly exerted no influence on the cutting through of the aorta by the ligature.

“The tissues around the vessel and in the vicinity of where the ligature was placed show a slight degree of swelling, and in addition there are found here and there small collections of plasma cells and a few lymphoid cells; further than this no change is observed.

“In conclusion, it may be said that while a very slight degree of atheromatous change is undoubtedly present in this aorta, the alterations are not so great as are very commonly found in the vessels of old people in whom there has never been the slightest tendency toward aneurismal dilatation of the vessels, and, therefore, the mechanism of the development of the original aneurism, which must have preceded the false one, is by no means so clear as would be desirable. However, in the absence of any other probable cause, it seems necessary to assume that the condition was the result of a particularly severe patch of atheromatous change occurring only in the situation where the opening in the vessel exists, and where a very small aneurism must have developed before the wall of the artery gave way.”

Before making any remarks I add a brief *résumé* of all the recorded cases of ligation of the aorta, including one by Tillaux, done since my own.

CASE I. (Sir Astley Cooper¹).—A porter, aged thirty-eight years, was admitted to Guy's Hospital, April 9, 1817, for an aneurism of the internal iliac artery, extending both above and below Poupart's ligament. It was, apparently, the result of a violent blow upon the left groin thirteen months prior to admission. Three days later the tumor doubled in size. Compression by a tourniquet was applied. This soon produced a slough, and on June 20th he had an external hemorrhage; again on the 22d, the 24th, and the 25th hemorrhages occurred, the last one being so severe that it seemed as though he would not recover. At 9 P.M. on June 25th the aorta was tied by a transperitoneal operation. The incision was in the linea alba, three inches long, half above and half below the umbilicus. The aorta was tied with a single ligature and the ends left long. Immediately after the operation touch on the right thigh was appreciated as a touch on the foot. The pulse was 144 at the time of operation. By one o'clock in the morning, three hours after the conclusion of the operation, the lower extremities were regaining their heat. Other parts of the body were covered with cold sweat. He was treated with opium and external heat. At noon the next day the temperature of the right leg was 94° F., that of the left 87.5° F. Incontinence of feces set in that evening, and incontinence of urine, of which he had passed almost none, began during the day of the 27th. The left leg was still livid and cold. He gradually sank, and died at 1.18 P.M., having survived the operation forty hours.

The *necropsy* showed no peritonitis, excepting at the edges of the wound, which were glued together. The ligature was applied three-quarters of an inch above the bifurcation. Above the ligature was a clot more than an inch in extent, and below there were two clots extending into both iliac arteries. (Figs. 4 and 5.)

In his remarks on the case Sir Astley says that Mr. Lawrence has proposed that the silk ligature should be cut off close to the knot, but he adds "it has occurred to me that catgut would answer the purpose better," on the ground that as it is an animal ligature it would be more easily absorbed. He then relates the case of a man, aged eighty years, who had a popliteal aneurism and whose artery was tied with catgut, both ends being cut short. The wound was not dressed until the fourth day, and was then found to be completely united.

CASE II. (J. H. James²).—A man, aged forty-four years. Case first thought to be hip-joint disease, there being no tumor; but later an enlargement appeared and diagnosis of aneurism made. Operation, June 2, 1829. Ligation of femoral half an inch below Poupart's ligament. On account of extensive sloughing transperitoneal operation on the aorta was resorted to July 5, 1829, 3.30 P.M. Incision in median line. Aneurism needle broke at the wooden handle in consequence of difficulty of inserting it behind the aorta. Great difficulty in passing the ligature around the vessel. When the ligature was tied the patient complained of "deadness in the lower extremities." The ligature was cut close. Great pain in both legs followed, especially on the aneurismal side, and continued until he died, at 7 P.M., three and a half hours after operation.

Necropsy the next morning at ten. The tumor was collapsed. In

¹ Cooper and Travers' Surgical Essays, Parts I. and II., p. 83.

² Medico-Chirurgical Transactions, 1830, vol. xvi., Part I.

FIG. 4.



Sir Astley Cooper's case. Anterior view.

a, a, aorta; *b*, its bifurcation; *c, c*, iliac arteries; *d*, superior mesenteric artery; *e, e*, renal arteries; *f*, duodenum; *g*, ligature; *h*, clot in left iliac artery.

FIG. 5.



Sir Astley Cooper's case. Posterior view.

a, a, aorta; *b*, its bifurcation; *c, c*, iliac arteries; *d, d*, duodenum; *c*, ligature; *f*, clot above the ligature; *h*, clot in left iliac artery.

the abdominal cavity there was a considerable quantity of blood, partly coagulated. This may have proceeded from a vessel in the abdominal wall or a vessel in the mesentery scratched by the broken needle. The point of ligation was five lines below the inferior mesenteric and eleven lines above the bifurcation. The sac was filled with laminated clot and some grumous blood. Some diseased spots in the aorta and clots both above and below the ligature. He says: "The great difficulty I experienced in this case arose from the tough investment of the artery, which I could hardly pierce with my nail."

CASE III. (Murray¹) — A man, aged thirty-three years, admitted to the Civil Hospital, at the Cape of Good Hope, January 22, 1834, with a tumor in the right iliac, hypogastric, and inguinal regions. It probably had existed for eight months. No pulsation was perceptible in the femoral artery. Pain was often very excruciating. The limbs were swollen and flexed. The skin was insensible to touch, especially on the inner part of the thigh; temperature 5° below the opposite one. On the 26th he was seized with agonizing pain, and his general condition was much worse. The leg had become quite cold and insensible. The tumor was evidently on the point of rupture. After friction with stimulating liniments the limb became warm again by the afternoon, but the integuments of the foot were of a bluish color. The only possible operation was deemed a ligature of the aorta.

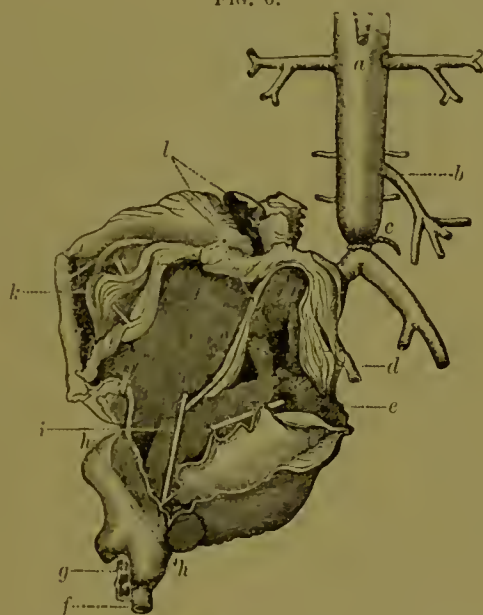
At the time of the operation (11 P.M.) the integuments of the instep and part of the leg were discolored, and the limb was again cold; pulse 120. Operation, January 26, 1834, by candle-light. Extraperitoneal operation. The most difficult part of the operation seems to have been the division of the membranous sheath covering the aorta, which was done chiefly by the finger-nail. At the time of ligation there was no noticeable alteration in the pulse; no congestion of the head. The tightening of the knot did not seem to give the patient any unusual sensation or shock [this was before the introduction of anæsthesia]. His first complaint was that his left leg had become as benumbed and useless as his right, and they had "done him a bad service in laming his good leg." Both ends of the ligature were cut long and hung out of the wound. He was able to move both legs fifteen minutes after the operation. Very soon a painful sensation of distention of the bladder was complained of. One ounce of urine was removed by the catheter, but the sensation was not relieved. His incessant cry for more than an hour was "my bladder will burst; why do you not pump my water off?" By 2.30 P.M. there was violent headache, with great beating of the carotid, while his pulse was scarcely perceptible at the wrist. The livid discoloration in the right leg had increased. At 5 P.M. it is noted that both legs continued "dead cold" in spite of external heat. He died at 9.50 P.M., twenty-three hours after operation.

Necropsy. An injection was thrown into the thoracic aorta and the body examined ten hours after death. There was no peritonitis. The bladder was vesicated on its internal surface and its coats considerably thickened. The left ureter, not injured at the time of operation, was dilated to the size of the little finger. The aorta was tied three to four lines above the bifurcation and one inch below the inferior mesenteric. (Fig. 6.) A small clot of blood existed above the ligature; none below.

¹ London Medical Gazette, 1834, vol. xiv. p. 68, and 1835, vol. xv. p. 6.

The immense aneurismal sac was filled with concentric layers of coagulated lymph and loose coagula of dark, thick, brown sanies. The iliac and psoas muscles were almost putrid, and the sac itself gangrenous in part. Murray points out that he believes the patient did not die from the ligature of the aorta, but "solely by the effect of his disease," as was shown by the gangrene and constitutional symptoms. He points out the fact that in a case of aneurism it is doubtful whether the operation will ever succeed, as the patient "must be so far advanced in danger before he could with propriety be advised to submit to a remedy attended with such imminent risk." He adds, however, that very possibly in cases of wound it would have a much better chance of success.

FIG. 6.



Murray's case.

a, aorta; *b*, inferior mesenteric artery; *c*, ligature on the aorta; *d*, right internal iliac artery; *e*, probe in external iliac artery (upper end); *f*, femoral artery; *g*, crural nerve; *h*, *h'*, imaginary line representing Poupart's ligament; *i*, probe in external iliac artery (lower end); *k*, layers of sac held open by quills; *l*, between these two points gangrene had commenced.

CASE IV. (Monteiro¹).—A man, aged thirty-one years, in perfect health. In July, 1842, after a long horseback ride, he began to feel excessive pain in the right groin. On examination he felt a tumor. The tumor rapidly increased and the pain became more severe, so that he consulted Monteiro on July 28th. A diagnosis of aneurism of the external and common iliac artery was made. Operation, August 5, 1842, 2 P.M. Extraperitoneal operation. One end of the ligature was left long. The operation lasted an hour and twenty minutes. The legs were cold; patient showed slight sweating and dyspnoea. By 6 P.M. the legs were no longer cold, but even warmer than before the operation. Thirst was intense, and the dyspnoea was less pronounced. On the third day the pulse was perceived in the femorals. He made a very excellent operative recovery. At the end of a week pus began to escape

¹ Rev. Méd.-Chir., 1852, vol. xi., p. 147; Lancet, 1842, vol. i., p. 334; and Schmidt's Jahrbüch., 1843, vol. xxxvii., p. 85, and 1852, vol. lxxv., p. 337.

from the wound. On August 14th there was hemorrhage at the point where the ligature protruded. This was followed by a number of hemorrhages. At 10 A.M., August 16th, he died, as a result of the repeated hemorrhages, ten days and twenty hours after operation.

Necropsy twenty-five hours after death. The wound was entirely closed except where the ligature protruded. The aorta was tied four lines from its bifurcation and one inch below the inferior mesenteric. The tumor contained nearly six pounds of coagulated blood, some of it laminated. Below the point of ligature there were some clots; above it there were none. The clots in the inferior portion were, however, small and incompletely obliterated the vessel. The knot of the ligature had perforated the aorta.

CASE V. (South).¹—June 21, 1856, 2 P.M. A man, aged twenty-eight years. Point of ligation a little above the bifurcation for a large aneurism of the right external and common iliac arteries. The aneurism rose above the umbilicus nearly to the cartilages of the ribs. Pulsation was felt with great difficulty. Distinct bruit by stethoscope. Sensation was lost in all of the right leg from pressure on the nerves. Extraperitoneal operation. The ligature was applied two lines above the bifurcation. This was the first operation under an anæsthetic. He died June 23d, 9 A.M., forty-three hours after operation.

Necropsy. The tumor was found to be a diffuse aneurism arising from the iliac artery.

CASE VI. (McGuire).²—Aneurism of external iliac. A man (negro), aged thirty years, while chopping wood, felt something give way in the lower abdomen a week before admission to the hospital. The tumor, about the size of a goose-egg, was in the left iliac and hypogastric regions. The pain was severe and increasing. Compression of aorta at intervals throughout the day and night of March 26th. This could be borne only for a few minutes at long intervals. After two or three hours the pain was so great that it had to be abandoned. Diarrhœa and fever; great tenderness and heat in the tumor. Operation, March 30th, 1 P.M. An attempt was made to ligate the common iliac. Extraperitoneal operation. Collateral circulation was already established, so that a large number of vessels required ligature. The condition found led McGuire to tie the aorta. In order to reach the aorta the tumor was caught between the finger and thumb; but in spite of delicate handling the sac suddenly burst, and a profuse discharge of blood took place. The finger at once placed upon the aorta an inch above the tumor completely arrested the hemorrhage until an assistant had surrounded the vessel with a ligature and tied it. About one pint of blood was lost. In a few minutes after being placed in bed, the body, which had been cold, became warm. At 5 P.M. he complained of numbness in the legs. At 6 P.M. one ounce of urine was removed by catheter. 7 P.M., sleeping quietly; lower extremities warm: skin pleasant. 10.30 P.M., restless; by midnight the pulse could not be measured, and he died at 12.30 A.M., eleven and a half hours after operation.

Necropsy twelve hours after death. No blood in the abdomen. The aneurism involved the aorta from the origin of the inferior mesenteric to the bifurcation and the right common iliac to its division into the external and internal and the left common and external iliaes. The

¹ Lancet, 1856, vol. II., pp. 47 and 222.

² THE AMERICAN JOURNAL OF THE MEDICAL SCIENCES, 1868, vol. Ivi. (N. S.), p. 415.

ligature was at the origin of the inferior mesenteric, and included the left ureter, which was deeply embedded in the cellular structure of the aneurism. It was difficult, even at the necropsy, to dissect the ureter from the wall of the sac without opening the cavity of the aneurism.

CASE VII. (Watson¹).—Operation, August 6, 1869. Common iliac had been tied antiseptically nine weeks previous with catgut. Secondary hemorrhage followed, and the aorta was tied by transperitoneal operation with a silk ligature half an inch above the bifurcation. The external and internal iliac arteries on the diseased side were also tied. The patient did well for forty-eight hours, but began to sink after the sixtieth hour, and died sixty-five hours after operation.

CASE VIII. (Stokes²).—A man, aged fifty years, accustomed to carrying heavy weights, temperate in habit, and never had suffered from any constitutional disease. Three months before, March 4, 1869, when he was admitted to the hospital, a tumor was first noticed in the right groin. A diffused iliofemoral aneurism was diagnosed two months later. The tumor occupied the right iliac and upper femoral regions, extending upward to within an inch of the umbilicus. Pulsation, fremitus, and loud bruit were present. Pressure was attempted, but the patient could not bear it. Operation, March 8th, 11.15 A.M., under chloroform. Extraperitoneal operation. The "chief difficulty in the operation," he states, was the separation of the peritoneum from the transversalis fascia. There was great difficulty from distention of the intestines. A Luer's needle was passed around the aorta just above the bifurcation, and attached to the ligature was a piece of silver wire, which was then drawn around the aorta. The ends of this wire were then seized in Mr. Porter's artery compressor and traction made on them until all pulsation and bruit had ceased in the artery. The ends of the wire were then secured to the ring of the clamp and the wound closed. Both legs were bandaged with flannel. The operation was almost bloodless. Hot-water bottles were tied to his feet and brandy and water given internally. The operation was concluded at 11.15 A.M. Fifteen minutes after the conclusion of the operation the pulse was 125, the color of the lips was good, and the temperature of the right leg and foot was lower than the left; no paralysis whatever; marked restlessness. Immediately after the operation he complained of paroxysmal pain in the ball of the great toe and sole of the same foot. At 2.30 P.M. the temperature in the left extremity was very good; right greatly improved. 9 P.M. pulsation of the left femoral had returned; in the tumor no pulsation or bruit. He died at midnight, about thirteen hours after operation.

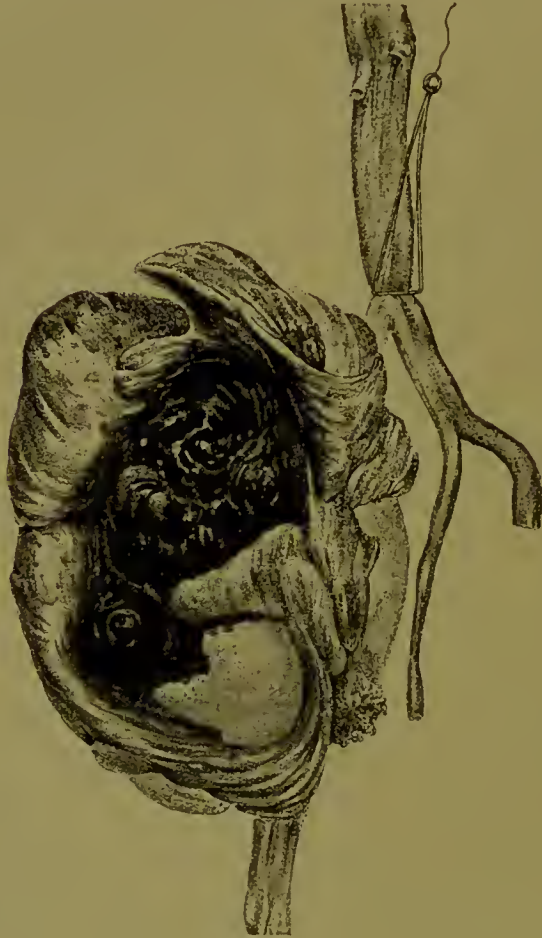
Necropsy the next day. Aneurism of the right common and external iliacs and femoral. (Fig. 7.) The bone was partly eroded. In the tumor there was a considerable amount of coagulated blood and some recently deposited fibrin. The instrument was removed with the greatest facility. It was found that not the slightest injury had been done to any of the coats of the aorta. Before opening the aorta the point of compression was found to be water-tight. He calls attention to the fact that the collateral circulation can be established in a very few hours, and also that speedy consolidation of the contents of an enor-

¹ British Medical Journal, 1869, vol. II., p. 216.

² Dublin Quarterly Journal, 1869, vol. XLVIII., p. 1.

mously diffused iliofemoral aneurism can take place after occlusion of the aorta. The death in his case was caused by the shock of the operation in a person with fatty degeneration of the heart.

FIG. 7.



Stokes' case.

CASE IX. (Czerny¹).—A soldier, aged twenty-seven years, on August 4, 1870, was wounded four finger-breadths below the left Poupart's ligament. The thigh bone was not fractured. On the 11th a severe hemorrhage took place. Ligature of the femoral artery both above and below the profunda. On the 13th there was loss of sensation in the left foot. This yielded to hot applications and alcoholic stimulants. On the 19th another severe bleeding at the point where the artery was ligated. The lower ligature had cut through. The common iliac artery was then ligated after failure to secure the bleeding-point. The hemorrhage from the femoral became less, but was not arrested. Renewed attempts to tie the profunda resulted in failure. Extraperitoneal operation on August 19th at 9 A.M. Believing that, as he had not seen the

¹ "Bericht ueber die in Weissenberg behandelten Verwundeten." Wiener medicinische Wochenschrift, 1870, p. 1402, and 1871, p. 103.

division of the artery, he had probably ligated the external iliac and not the common iliac, he carried his incision a little further up, stripped off some more of the peritoncum, and found, about three-quarters of an inch higher, the division of the artery into two parts. "Although the thought came to me for a moment that the vessel which had been tied might be the aorta, this idea seemed so improbable that I did not examine the pulsation of the right femoral." One end of each of the two ligatures was cut short and the other brought out of the wound. In the afternoon his condition was hopeful; the pulse was 136; the injured leg, however, did not again become warm. The next morning at eight o'clock the left thigh was greatly swollen, discolored, and the whole extremity cold and dead; the right warmer, movable, and sensible. At 12 M. he died, twenty-seven hours after the beginning of the operation.

Necropsy. No peritonitis. [No mention is made of any antiseptics.] The two abdominal ligatures were found to be: the first, just above the bifurcation of the common iliac; the other on the aorta itself. (Fig. 8.) The ligature on the aorta was impermeable to water. At the ligature of the aorta there was only a peripheral thrombus. Death took place from acute sepsis and hemorrhage. The collateral circulation must have been re-established very soon, as in the right leg there was no visible disturbance of the circulation.

CASE X. (Czerny¹).—A man, aged fifty years. Large tumor of the left kidney. Operation, January 19, 1879. Cœliotomy. The outer layer of the descending mesocolon was divided and blunt dissection begun. It was soon found that the soft tumor mass had broken through not only the capsule, but the inner layer of the mesocolon. Very profuse bleeding occurred, which could be controlled only by temporary compression of the aorta. As soon as this was relaxed the hemorrhage began again. Accordingly the aorta was tied and the hemorrhage ceased. [The paper does not state whether the tumor was removed or the operation abandoned.] Two hours after the closure of the abdominal wound anæ-

FIG. 8.



Czerny's first case.

a, aorta; b, inferior mesenteric artery; c, middle sacral artery; d, common iliac artery; e, external iliac artery; f, profunda femoris artery.

¹ "Ueber Nierenexstirpation." *Centralblatt für Chirurgie*, 1879, vol. vi., p. 737.

thesia and paralysis of the lower extremities set in, and ten hours after the operation he died.

Necropsy. The renal artery was torn close to its entrance into the tumor. The ligature around the aorta lay diagonally between the two renal arterics, so that the right renal was not obstructed, but the left was entirely closed.

CASE XI. (Milton¹).—An Egyptian, aged forty-five years, admitted to the hospital July, 1890. For sixteen months he had had a pulsating tumor in the abdomen, with severe paroxysmal pain. He had had syphilis, but never received any injury. The tumor was the size of an orange, and lay a little above the umbilicus. An operation was planned by Mr. Milton as follows: "To incise the abdominal walls for about five inches in the middle of the linea alba, to expose and incise the peritoneum covering the aorta one inch above the aneurism, separate the aorta from the vein, and then pass a blunt director on either side of the vertebræ, and to force it gradually backward through the tissues until its point could be cut down on in the back; then to make a similar passage on the other side; then to pass a small drainage-tube along the two channels made by the director, forming a loop across the aorta, the two ends of the tube presenting in the back on either side of the vertebral column—the tube being in position, to close the peritoneum over it with catgut sutures, and finally to completely close the abdominal incision. The idea was to leave the patient a few days, and then to compress the aorta against the vertebral column by traction on the two ends of the drainage-tube. The amount of pressure to be applied and the period of its application were to be regulated by the effect produced on the patient." Before this could be done, however, July 3d, the patient awoke with severe pain, and the aneurism evidently had suddenly ruptured. The rounded tumor could no longer be differentiated, but formed part of a pulsating mass extending from the umbilicus into the whole left hypochondrium. The aorta was compressed until it was ligated eight lines above the origin of the aneurism. The effused blood was retroperitoneal. Duration of operation but twelve minutes. Death took place, at the end of twenty-four hours, of anæmia and shock. He had complained of intense pain and tingling in both legs up to the time of his death. Thirteen ounces of urine, free from albumin or blood, were passed.

Necropsy. Aneurism purely aortic; lower limit three-quarters of an inch above the bifurcation; upper limit an inch and a half below the renal arteries, both of which were above the point of ligation. Four pounds of blood were found behind the peritoneum. All organs were anæmic, but otherwise healthy. Kidneys normal.

CASE XII. is the case reported in this paper.

CASE XIII. (Tillaux¹).—A man, aged fifty-six years, who had suffered with an aneurism of the left iliac for a year. On January 20, 1900, it ruptured and produced a diffuse aneurism as large as an adult head and reached almost to the umbilicus. The common iliac, as was supposed, was tied as high as possible with a silk thread by the transperitoneal route. There was no pain nor circulatory disturbance afterward; no alteration of the sensibility; the temperature on the left side was 35.4° (C.), and on the right side it was 34.6° (C.). After several

¹ Lancet, 1891, vol. 1., p. 85.

² Bull. et Mém. Soc. de Chir., Paris, May 8, 1900, p. 473.

days the tumor gradually increased in size, with a return of slight pulsation. He gradually grew thinner and showed evidence of venous congestion, with retention of urine. He died thirty-nine days after the ligation. The *necropsy* showed that the later phenomena were due to thrombosis of the femoral vein. The ligature, instead of being placed on the common iliae, as had been supposed, had been placed on the aorta immediately above the bifurcation. Nothing is said in this preliminary report as to the condition of the aorta above and below the point of ligation, as to the circulation in the other leg, the condition of the kidneys, or the spinal cord; but Prof. Tillaux has kindly informed me that there was no ulceration at the point of ligation. The aorta was not completely obstructed by the ligature, as a grooved director could be passed.

REMARKS. The remarks that I have to make can be best divided into (1) the remarks on the case herewith reported and (2) on the general subject of the cure of aortic or iliac aneurism by ligation of the aorta or other means.

1. *Remarks on the Present Case.* The first question that presented itself to me was whether the ligature had not slipped and failed wholly to occlude the aorta, as actually occurred in the able hands of Prof. Tillaux. This was especially suggested to me by the large loop which the ligature showed, as revealed by the necropsy (Fig. 2). In order to determine this positively I removed the loop of the ligature from the specimen and stretched it between two pins. The distance between the two pins was 21 mm. I then obtained a fresh aorta and ligated that as tightly as I could, and on removing the loop found that it measured 19 mm. between the two pins. This convinced me that the ligature did really occlude the aorta, for on comparing the fresh aorta with the specimen I found that the aorta from my patient was somewhat wider than the fresh one.

Additional evidence—the absence of pulsation in the femorals after the operation was concluded, and its *gradual* return, the absence of pulsation in the aneurism, which, as described, was somewhat difficult at first to determine positively, and the diminution in the size of the aneurismal sac—convinced me that the aorta was entirely occluded. It is also to be noted that when I tied the fresh specimen it did not pucker conically at the site of the ligature, but was folded over upon itself. This would increase remarkably the size of the loop.

The site of the ligation in reference to the branches of the aorta could not be determined with absolute accuracy from the specimen when I first saw it. It was certainly applied just below the diaphragm, as the pillars of the diaphragm were recognized at the time of operation. Whether above or below the coeliac axis was not quite certain, but it was surely applied above the renal and the mesenteric arteries. In view of the position of the ligature, it is remarkable that the post-

mortem showed no changes in the kidneys, and that the amount of urine passed, though much diminished in the first few days following the operation, was not much less than often follows any other operation.

I regretted very much that the necessary haste with which the post-mortem was made prevented the removal of the spinal cord and its microscopic examination. So far, however, as the clinical symptoms went, there was no marked change in either sensation or motion. The cutting off of the circulation produced a coldness in both lower extremities, which, however, soon passed away, and later the man was able not only to move his legs, but to get out of bed and even to walk with his usual strength. One very marked symptom was observed immediately after the ligation of the aorta—the very deep congestion of the upper portion of the body. This explained to me more forcibly than I had ever appreciated before the enormous dilating force of the blood-current and the means by which the collateral circulation is established.

In only three of the cases reported is the time given at which the femoral pulsation was observed to be re-established. In Stokes' case (VIII.) the femoral pulse was observed in ten hours; in Monteiro's case (IV.) on the third day, and in my own it was observed a little over five hours after the conclusion of the operation. Its early re-establishment, it seems to me, was probably due to the partial collateral circulation already in existence by reason of the aneurism. In Czerny's first case (IX.) the collateral circulation, as he says, must have been re-established very soon, as there was no visible disturbance of the circulation in the other leg. In 1864, in a case of ligation of the common carotid, I observed the re-establishment of the temporal pulse on the side of the ligation in five and a half hours after the operation.¹

The experiments upon animals by Sonnenburg² present some very remarkable results in reference to the collateral circulation after ligation of the aorta. First, a manometer was placed in the central end of the femoral artery, and the aorta was then compressed and finally tied. When digital compression was applied, or when the ligature was tightened, the blood-pressure fell gradually, but did not reach the zero. When the ligature was permanently tied the pressure *fell from 110 mm. of mercury to only 66 mm., but after 300 seconds began to rise again, and after 700 seconds pulsation was perceptible.* The manometer was then placed in the peripheral end of the femoral and the aorta tied. The pressure again fell, but not so quickly as in the first instance, and the pulse also returned, but at what time is not mentioned.

Kast³ also reports some experiments on animals in which he placed a manometer in the central end of the femoral of a goat. As soon as

¹ THE AMERICAN JOURNAL OF THE MEDICAL SCIENCES, July, 1864.

² Centralblatt für Chirurgie, 1876, p. 689.

³ Deutsche Zeitschrift für Chirurgie, 1880, vol. xii., p. 405.

the aorta was tied the pressure fell from 20 mm. not entirely to zero, and after only two or three seconds rose to 17 mm.

2. *Remarks on the Cure of Aortic Aneurism by Ligation of the Aorta or Other Means.* On reviewing the thirteen cases of actual deligation of the aorta in man in connection with the numerous experiments on animals which have been made on this subject, three propositions, it seemed to me, are well established.

(1) The human subject can survive after ligation of the aorta without serious mischief. Ten of the cases have died very shortly after the operation, but three of them have survived sufficiently long to establish the truth of this proposition. Monteiro's case survived ten days and twenty hours; Tillaux's case survived thirty-nine days, and my own case survived forty-eight days. These show distinctly that the collateral circulation can be established sufficiently early to preserve the lower limbs from gangrene and the cord from such changes as will produce a permanent paralysis.

No certain conclusions can be drawn as to the effect of the ligature on the vessel in Tillaux's case, since the lumen of the vessel was not entirely closed, but Monteiro's case and my own show that with the ordinary ligature, whether single or multiple, death will almost certainly result from the cutting through of the ligature and secondary hemorrhage. The diagram (Fig. 9) shows the reason for this.

The aorta is very elastic. With each pulsation there must be marked dilatation of the vessels above the ligature, and this constant tugging must eventually result, in my opinion, in all cases in ultimate ulcerative absorption, rupture, and death.

I had in mind at first the substitution of a broad, flat band which would occlude the aorta over a considerable space, and thus mechanically avoid the cutting action of a ligature. A serious objection to this would be that the knot in any band, such as a piece of tape or a silk ribbon sufficiently broad to attain the object in view, would be very bulky, and instead of being absorbed would almost certainly give rise to trouble. This led me to devise the instrument which is described below.

We can also appeal for instruction to the considerable number of cases of occlusion of the aorta by either a thrombus or an embolus, referred to by Welch.¹ In this exhaustive paper Welch has collected

FIG. 9.



To illustrate the expansible tug on the ligature, necessarily causing its ulceration through the walls of the aorta.

¹ Allbutt's System of Medicine, American edition, vol. vii., p. 273.

fifty-nine cases of occlusion of the aorta. Fifty-six of these were followed by death, very commonly from gangrene. Even if the patient, therefore, should survive the shock of the operation, the chances of recovery would be but small.

(2) The treatment of aortic aneurism by temporary compression of the aorta by means of a tourniquet has given what may justly be called excellent results, especially as compared with ligation. This method, as is well known, was devised in 1864 by Murray,¹ of Newcastle-on-Tyne, who, for the first time, tried instrumental compression, and with entire success. The pressure was made through the abdominal wall by a tourniquet, first on April 16th for two hours, and on a second occasion, April 19th, for five hours, the patient being continuously under chloroform on both occasions. The circulation was not completely and permanently suspended except for the last hour of the second attempt. In Ashhurst's *International Encyclopædia of Surgery*, vol. ii., p. 928, which was published in 1889, Barwell states that ten cases had been reported up to that time, of which five were successful, four died, and in one case no cure was effected. Pressure was kept up in some of the cases for five, ten, and ten and a half hours. The cases that resulted fatally died as a result of *bruising of the intestines*, which could not be displaced from underneath the tourniquet.

I have not sought in the literature on the subject for any additional cases since that date, but the presumption would be that the mortality-rate would be about the same.

(3) The third proposition is that in suitable cases of aortic or iliac aneurism, in view of the safety from infection which our modern antiseptic methods give us, the abdomen should be opened and an instrument applied to the aorta which would suitably compress it, not with a view to the permanent obliteration of its calibre, but, following Murray's method, for a temporarily complete or almost complete occlusion of the lumen of the aorta. By its application through an incision injury to the intestines could be avoided with absolute certainty. The instrument should be so constructed that the compression could be regulated, relaxed, and renewed at pleasure; and, finally, when consolidation of the aneurism has been effected, the instrument could then be withdrawn and the abdominal wound closed.

In Milton's case the very ingenious plan which he devised, but was prevented from employing, was as follows: That the abdomen should be opened, the aorta isolated, and the two ends of a drainage-tube passing over and in front of the aorta should make their exit through two openings on either side of the spine. The two ends could then be tied and the pressure relaxed or increased as desired, the tube being

¹ Medico-Chirurgical Transactions, vol. xlvii., p. 187; Lancet, February 8, 1873, p. 193.

removed when the object had been attained. The two most serious objections which seem to me to lie against this plan are, first, that structures other than the aorta would be liable to injury, especially the thoracic duct, and, secondly, the possibility of infection and the more extensive injury, neither of which, however, need be taken too seriously.

The instrument that I have devised avoids the danger just alluded to—of pressure on the thoracic duct—and requires only the opening of the abdomen and its application to the vessel. It consists of two parts (Fig. 10): First, a shank with a horizontal plate, which passes at right angles to the shank behind the aorta. The aortic surface is slightly roughened, in order to prevent slipping. Secondly, a second shank, with another horizontal plate, which can be introduced separately and fastened to the shank of the first piece by slipping the narrowed portion under the two projecting teeth of the first shank. This upper horizontal plate is also slightly ribbed on its under surface and provided with a lip which overlaps the lower horizontal plate, the object of the lip being to prevent the slipping of the aorta from the grasp of the blades.

I have measured the human aorta, and find that when flattened out it measures about 36 mm. transversely. This would give the proper measurement for the width of the plates. In order to make the narrowing of the aorta a conical or gradual one, instead of the abrupt narrowing caused by the ligature, the sides of the upper horizontal plate shelf gently upward. For application to the human subject the length of the plates should be about 15 mm. in the horizontal portion, the shelving portion at the upper and lower border being about 5 mm. each. The length of the shanks or handles would be greater or less in accordance with the build of each patient. In a very stout person they would have to be much longer than in a thin patient. The instrument can be introduced either as a whole, or, probably more readily, in two parts, which are then fastened together by passing the narrow portion of the handle of the upper blade into the grasp of the two prongs or teeth on the handle of the lower blade. By means of the screw at the upper end the upper blade is now gradually approximated to the lower, and when an assistant, with his finger on the femoral artery, finds that the pulsation has disappeared, occlusion of the aorta would be complete. By means of the little crossbar and by unscrewing the screw the upper blade can be retracted to any desired extent. By this manipulation it is evident that the circulation can be absolutely arrested or can be reduced to any degree that is desired. By this means Murray's method of temporary compression can be adapted to the aorta for any length

FIG. 10.



of time desired, in accordance with the effect of the anæsthetic, the general condition of the patient, and the effect upon the aneurism. Indeed, I am not at all sure that the patient would have to be anæsthetized during the entire sitting. Very possibly when the aorta has been occluded the anæsthetic might possibly be withdrawn and only renewed when the instrument is to be removed. Experience may show that even this is not required. With the modern antiseptic methods I believe it would be possible to retain the instrument in position for two or three days and reapply the pressure at any time, removing the instrument entirely when the attempt has been either successful or would be best abandoned. In removing it, it might be removed as a whole, or, if desired, in two parts.

EXPERIMENTS UPON ANIMALS WITH THE INSTRUMENTS JUST
DESCRIBED.

At my request Dr. J. C. Keeler performed the following experiments upon some dogs, in order to test this instrument. Female dogs were selected, so that the abdominal bandages might not be soiled with the urine. All the usual antiseptic care was taken, and each dog, after recovery from the chloroform, if there were any symptoms of pain, received suitable doses of morphine to relieve her. In each case, unless otherwise stated, the aorta was clamped just below the renal artery.

Experiment I. March 10, 1900, 4 P.M., small dog. The clamp was placed in two separate pieces on the aorta and tightened until complete obliteration of the femoral pulse was observed. The hind legs were found to be paralyzed as soon as the dog recovered from the anæsthetic. She was, therefore, slung with bandages. Respiration soon became rapid and shallow; all nourishment was refused, and six hours after the operation death ensued. The post-mortem showed the clamp in place 2.5 cm. below the renal arteries; the lungs were congested.

Experiment II. March 19, 1900, 3 P.M., large dog. The clamp was placed on the aorta as a whole instead of in separate pieces, and was then tightened until the femoral pulse had ceased. Six hours and a half later the femorals were pulsating strongly, and it was found that the clamp had slipped from the aorta. The clamp accordingly was removed in two parts and the wound closed. For two days the dog was partially paralyzed in the hind legs, but showed no discomfort, and soon was entirely restored to health. The slipping was due to the fact that the upper blade which clamped the artery had not a sufficiently long curved lip to prevent it from slipping. The lip was then slightly lengthened and the following two experiments performed with the modified instrument. I might add also that Dr. Keeler and also Mr. Schneyder, the instrument maker, had suggested several other minor improvements.

Experiment III. April 9, 1900, 3 P.M. The same dog as in Experiment II. The aorta and the part involved in the prior operation were found firmly bound down by adhesions. Accordingly the clamp was adjusted as a whole just above the bifurcation of the aorta. The aorta

was then compressed so as to obliterate the pulsation of the femorals. Twenty-four hours after the operation distinct pulsation could be felt in the femorals. How much earlier it had been present could not be determined. Forty-three hours later the clamp was tightened so as to obliterate the pulsation, and it remained in place until the one hundred and tenth hour. For the first four hours paralysis of the hind legs was noticed; after that time she walked with a tottering gait. Food was heartily taken, and everything looked toward a speedy and complete recovery. The clamp, however, became entangled in the bandages as an attempt was about to be made to remove it, the aorta was torn, and death ensued immediately.

[In all probability the minor effects following the later entire occlusion were due to the establishment of the collateral circulation by the partial occlusion of the aorta at the first attempt.]

Experiment IV. April 20, 1900, 2.15 p.m. The clamp was placed in position in two parts and tightened so as to obliterate the femoral pulsation. Paralysis of the hind legs immediately followed. Three and a half hours later the elamps were removed, one blade at a time, the pulsation re-established, and the paralysis disappeared.

The conclusions from these operations are: (1) that in dogs paralysis of the hind legs follows complete obliteration of the aortic stream; (2) that the paralyzed parts may regain their entire health even after forty-eight hours' compression; (3) that three and a half hours of compression will not interfere with the complete restoration of the paralysis; (4) that at least after twenty-four hours, and possibly less, the collateral circulation may re-establish the continuity of the circulation; (5) that the aorta may be elamped in the dog for one hundred and ten hours, and yet the collateral circulation be established sufficiently to nourish the posterior extremities; (6) that the clamp can be placed on the aorta, at least in the dog, either in separate parts or as a whole, and (7) that it can be readily removed without injury to the aorta.

